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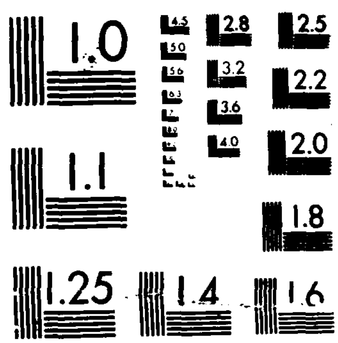

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EVALUATION OF THREE MILITARY DIESEL INJECTION SYSTEMS ON ALTERNATIVE FUELS

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BFLRF No. 214

By

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Under Contract to

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Fort Belvoir, Virginia

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Army diesel-powered vehicles are often required to operate in remote areas and in extreme ambient conditions, e.g., arctic or desert areas. Use of emergency fuels with less than optimum properties can result in unsatisfactory engine performance. This study examined the relationship between front-end volatility of the fuel and vapor lock at high fuel temperatures and the relationship between high viscosity fuels and pump-filling problems at low fuel temperatures. Three Army diesel injection systems representing the majority of Army equipment were selected for testing. Fuel flow rate tests were conducted at both high and low fuel temperatures and at a variety of operating conditions. Test fuels were blended to provide fuels with a range of 10 percent points for the high-temperature tests and fuels with a range of viscosities for the low-temperature tests. The front-end volatility of the fuel was not observed to present any problems at the high temperatures. However, fuel viscosity at both high and low temperatures was observed to affect the fuel flow rate for each injection system. Fuels with relatively low viscosities tended to leak past the barrel and plunger assemblies, resulting

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in a decrease in fuel flow rate. The fuels with the higher viscosities tended to have problems completely filling the pump in the time available. Thus, use of these fuels also resulted in decreased fuel flow. The decrease in fuel flow rate would result in a reduction in maximum power output.

FOREWORD

This work was conducted at the Belvoir Fuels and Lubricants Research Facility (SwRI) located at Southwest Research Institute (SwRI), San Antonio, TX under Contract No. DAAK70-85-C-0007 during the period November 1984 through December 1986. The work was funded by the U.S. Army Belvoir Research, Development and Engineering Center, Ft. Belvoir, VA, with Mr. F.W. Schaekel (STRBE-VF) as the Contracting Officer's representative and Mr. M.E. LePera, Chief of Fuels and Lubricants Division (STRBE-VF), as the project technical monitor.

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I. INTRODUCTION

Army diesel-powered vehicles are often required to operate in remote areas and in extreme ambient conditions. These conditions can range from an arctic surrounding with sub-zero temperatures to desert terrain with extremely high temperatures. Fuels for these vehicles cannot always be expected to have the optimum fuel properties for these conditions. Also the use of emergency fuels with less than satisfactory properties may be required.

Several problems can occur. At high ambient temperatures, the fuel temperature can be expected to increase. Thus, vapor lock in the fuel lines may occur, resulting in reduced power or inability to operate. At low ambient temperatures, the diesel fuels will have high viscosity, which can result in pump-filling problems and reduced power. In an extreme case, the cloud point of the diesel fuel may be exceeded, and filter plugging would become a problem.

II. OBJECTIVES

The objectives of this study were to; (1) examine the relationship between front-end volatility of the fuel and vapor lock at high fuel temperatures, and (2) to examine the relationship between high viscosity and pump-filling problems at low fuel temperatures.

III. INJECTION SYSTEMS

Injection systems used in this study were selected from diesel engines representative of the current Army inventory of diesel engines. Equipment both in the continental United States and outside the continental United States were included in determining those engines most abundant in the Army inventory. TABLE 1 (1)* lists the total number of vehicles and total fuel consumption for seven classes of Army vehicles that use diesel engines. As indicated in the table, three classes--2-1/2-ton truck, 5-ton truck, and track vehicles—comprise the majority of equipment and consume the majority of the fuel. TABLE 2 (1) lists the engines typically found in these three classes of vehicles.

* Underscored numbers in parentheses refer to the list of references at the end of this report.

TABLE 1. Density Listing of Army Diesel Vehicles

Vehicle Class	Fuel Consumption		Equipment	
	Gallons	Percent	On-Hand	Percent
1-1/4-ton truck	2,267,095	3.20	9,723	8.38
2-1/2-ton truck	28,330,538	39.96	55,962	48.26
5-ton truck	21,715,769	30.63	19,466	16.79
8-ton truck	439,231	0.62	714	0.62
10-ton truck	2,251,500	3.18	657	0.57
HET truck	6,172,129	8.71	6,449	5.56
Tracked Vehicles	9,717,335	13.71	22,999	19.83
TOTAL	70,893,597	100.00	115,970	100.00

TABLE 2. Summary of Diesel Engines Used in Selected Vehicle Classes

Vehicle Class	Engine	Fuel Consumption		Equipment	
		Gallons	Percent	On-Hand	Percent
2-1/2-ton truck	LD-465	28,330,538	47.40	55,962	56.86
5-ton truck	LD-465	6,676,627	11.17	6,612	6.72
	NHC-250	15,039,142	25.16	12,854	13.06
Tracked Vehicles	6V-53(N/T)	3,598,542	6.02	12,676	12.88
	8V-71T	1,628,672	2.73	4,229	4.30
	AVDS 1790	4,490,121	7.51	6,094	6.19
TOTAL		59,763,642	100.00	98,427	100.00

As indicated in TABLE 2, three types of engines--Continental LD-465, Cummins NHC-250, and Detroit Diesel Allison 6V-53(N/T)--represent the majority of equipment used in these vehicles.

The fuel injection systems from these classes of engines were, therefore, selected for testing. The LDT-465-1A engine utilizes a distributor-type injection pump. This particular injection pump incorporates a density compensator that, theoretically, adjusts the fuel flow rate to compensate for fuels with densities different from a standard DF-2 fuel. The NHC-250 engine utilizes a pressure-time (P-T) type injection system, and the 6V-53 and 8V-71T engines use unit injectors.

IV. TEST FUELS

The test fuels were selected to provide fuels with a broad range of front-end volatility and a broad range of viscosity. The front-end volatility was varied by blending JP-4 with a standard DF-2, while the viscosity was varied by blending a high viscosity fuel with a standard DF-2. The three stock fuels were a JP-4, a DF-2, and a Telura process oil. The properties of these fuels are shown in TABLE 3. Test fuels were formulated using various quantities of the blending components. Test fuels varying the front-end volatility consisted of JP-4/DF-2 blends with 10-, 25-, 50-, and 75-percent JP-4. Fig. 1 illustrates the effect of percent JP-4 on the 10-percent point, a measure of front-end volatility. Test fuels used for the high-viscosity fuels were TL-373/DF-2 blends with 33- and 67-percent TL-323. The TL-323 fuel was also included as a test fuel for the low-temperature tests. Baseline DF-2 was used as a reference fuel. The fuel viscosity as a function of percent Telura oil (TL-323) is shown in Fig. 2. This figure also illustrates the effect of JP-4 concentration on viscosity of the JP-4/DF-2 fuel blends.

TABLE 3. Summary of Fuel Properties for Blend Components

	ASTM Method	JP-4 AL-8906-F	DF-2 FL-0290-F	Telura 323 FL-0391-F
Specific Gravity, 60°F (16°C)	D 1298	0.7523	0.8565	0.9030
Gravity, API	D 1298	56.5	33.7	25.2
Cloud Point, °F (°C)	D 2500	—	12 (-11)	--
Viscosity, cSt	D 445			
20°C		0.81	4.54	--
40°C		0.64	2.89	21.4
100°C		—	--	3.5
Distillation, °F (°C)	D 2887			
10		154 (68)	405 (207)	627 (331)
50		236 (113)	513 (267)	679 (359)
90		310 (154)	636 (336)	762 (405)

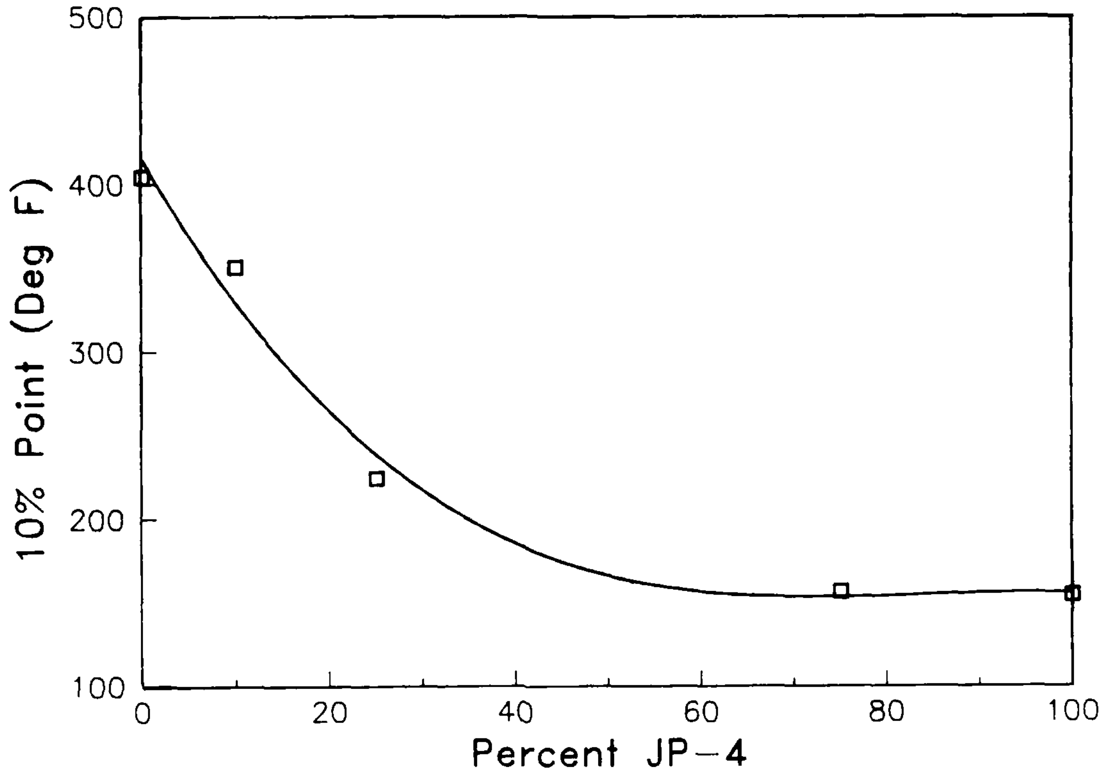

Figure 1. <u>**10% point versus percent JP-4 in DF-2**</u>

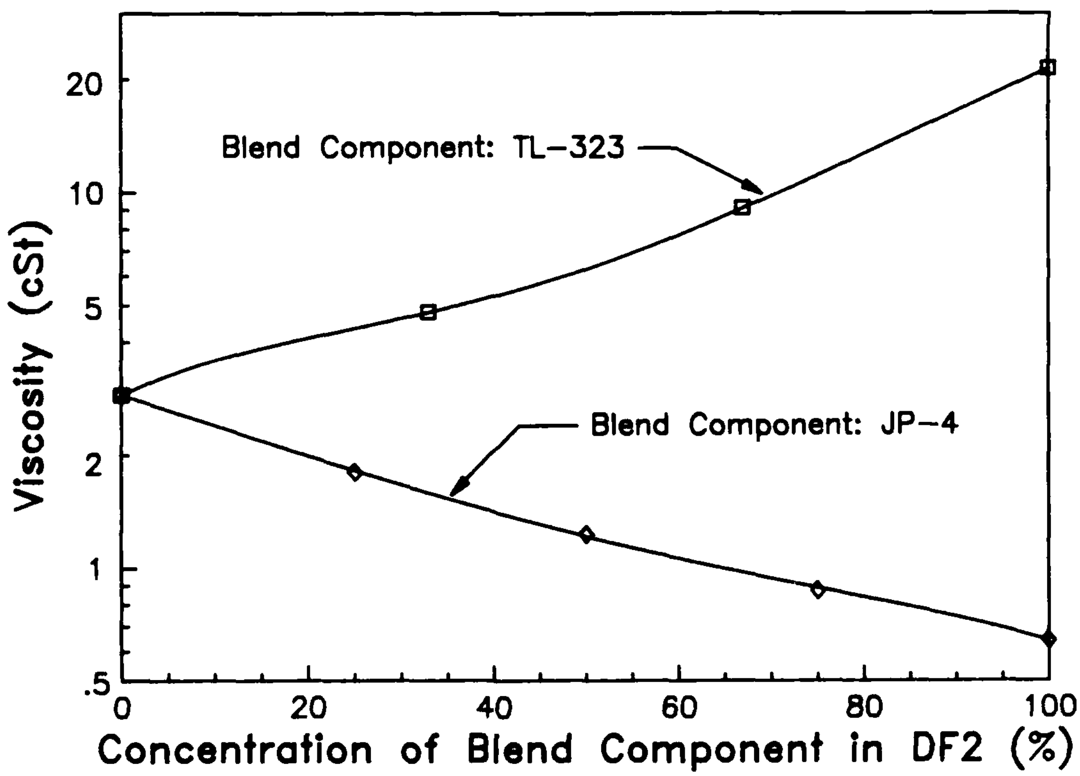

Figure 2. Fuel viscosity versus concentration of blend component in DF-2 at 40°C

V. TEST CONDITIONS

The fuel temperature was varied to simulate extreme ambient conditions. At high ambient temperatures, the fuel can absorb a significant amount of heat from the fuel pump and engine. Studies have shown that for the LDT-465-1A and the 6V-53 engines, the temperature of the fuel in the tank can reach 85°C when the vehicle is operated in a desert-type environment.(2) Therefore, fuel temperatures at inlet to the fuel injection pump can also be expected to reach 85°C. Naturally the temperature of the fuel in the pump would be affected by the amount of heat generated by the pump. However, for all of the tests discussed in this report, the temperature at the inlet to the fuel injection pump was controlled as the experimental variable. The fuel, fuel lines, and fuel injection pump were heated to maintain the desired fuel temperatures. Fuel temperatures at the inlet to the fuel injection pump for the high-temperature test ranged from ambient (27°C) to 85°C.

Low-temperature tests were limited in temperature by the cloud point of the test fuels. One of the main objectives of this study was to investigate pump-filling characteristics at low temperatures for high viscosity fuels. It was beyond the scope of this study to examine problems related to cloud-point effects. Therefore, all tests were conducted at a fuel temperature above the cloud point. Fuel temperatures for the low-temperature tests ranged from ambient to approximately 30°F (-1°C). Fuel viscosities at these temperatures ranged from 2.5 to 40 cSt.

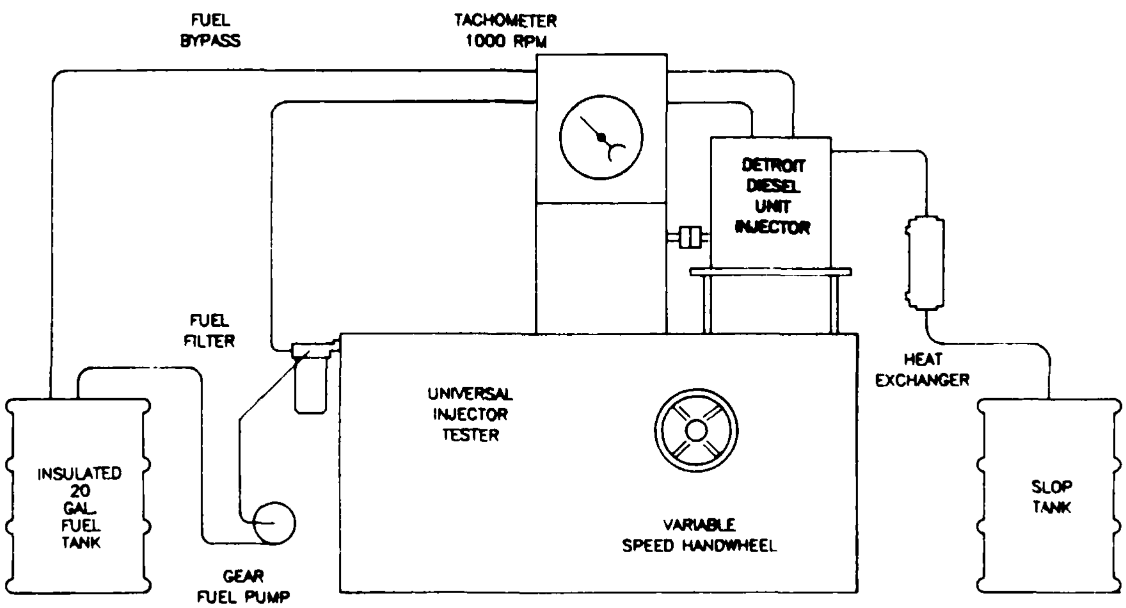

Figure 3. Detroit diesel injector bench test apparatus

A schematic of the experimental apparatus is shown in Fig. 3 for the DDA 6V-53 heated injection system. The fuel reservoir was an insulated 20-gallon drum that could be or cooled to the desired temperature. Fuel was supplied to the unit injector by an auxiliary fuel pump. The fuel lines and injector were insulated and, for the high-temperature tests, were supplied with external heat to maintain the desired fuel temperature at the inlet to the injector. The experimental set-up for the Continental LDT-465-1A engine and the Cummins NHC-250 engine were similar.

Pump-filling problems at low temperatures and vapor lock at high temperatures might be expected to occur for some fuels at some engine-operating conditions. These problems would result in reduced fuel flow rates and, hence, reduced power at these conditions. The fuel flow rates were measured for the various test fuels at different test temperatures. The DF-2 fuel and JP-4/DF-2 blends were tested at high-fuel temperatures. The DF-2 fuel, the TL-323/DF-2 blends, and the TL-323 fuel were tested at the low ambient temperatures. The fuel flow rates for each fuel at several temperatures were measured for a variety of injector-operating conditions from low flow to full-rack. For the LDT-465-1A, the injection system was operated at 1300 and 2600 rpm. The DDA 6V-53 injector was operated at 1000 rpm, and the NHC-250 injector was operated at 500 and 1000 rpm.

VI. RESULTS

The front-end volatility of the fuel was not observed to present any problems at the high temperatures. The 75-percent JP-4/DF-2 blend had a 10-percent distillation point of approximately 70°C. This was well below the maximum fuel test temperature of 85°C. However, even with this fuel blend, no vapor lock problems were evident under the conditions tested. Based on these data, a slight increase in the fuel temperature as it enters the injection pump would not be expected to affect the results using this test method.

Viscosity at both high and low temperatures was observed to affect the fuel flow rate for each injection system. The effect of viscosity on the fuel flow rate was determined by using regression analysis to relate the fuel flow rate to fuel viscosity, pump speed (rpm), and rack position or fuel pressure. The results of the regression analysis are discussed in the following sections for each injection system.

A. Continental LDT-465-1A Injection System

The LDT-465-1A injection system was operated at two different speeds--1300 and 2600 rpm. Data for these two speeds were analyzed separately using regression techniques. For each speed, fuel flow rate, measured in mL/1000 strokes, was related to rack position and fuel viscosity. Fig. 4 plots the fuel flow rate versus rack position for baseline DF-2. At 1300 rpm the fuel flow was directly proportional to rack position. The fuel flow rate at 2600 rpm was not linearly related to the rack position so an additional term, rack position squared, was required in the regression equation. The form of this equation is illustrated by Eq. (1).

$$\text{FFLW} = b_0 + b_1\,(\text{RACK}) + b_2\,(\text{RACK}-0.5)^2 + b_3\,[\log(\text{VIS})] + b_4\,(\text{VIS})^{-1} \quad (1)$$

where:
- FFLW = fuel flow rate (mL/1000 strokes)
- RACK = nominal rack position
- VIS = fuel viscosity at test temperature (cSt)

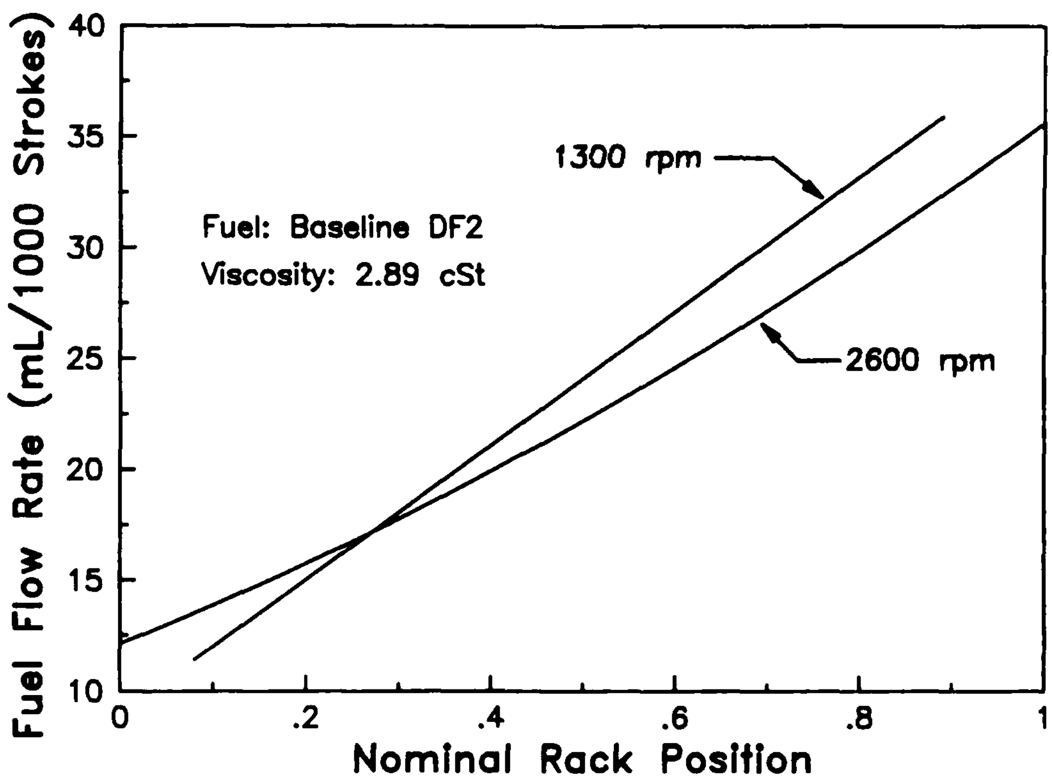

Figure 4. Fuel flow rate versus rack position for LDT-465-1A

The results of the regression analysis are presented in TABLES 4 and 5 for the 1300 and 2600 rpm data, respectively. As indicated by the R^2 values, 0.9760 for the 1300 rpm data and 0.9794 for the 2600 rpm data, a good fit to the data was obtained with the regression equation, Eq. (1). (An R^2 of 1.00 is a perfect fit.) The coefficients on the viscosity terms are similar for both speeds. The effect of viscosity on the fuel flow rate is illustrated in Fig. 5 for the full rack - 2600 rpm condition. As shown, the maximum flow rate was obtained with a fuel viscosity of approximately 3.0 cSt. As fuel viscosity varies from this value, a decrease in fuel flow rate occurs. For lower viscosities, this decrease was attributed to increased leakage of the fuel past the injection barrel and plunger. The decrease in fuel flow rate at the higher viscosities was attributed to pump-filling problems. These effects were observed at both speeds and all rack positions.

TABLE 4. Results of Regression Analysis for Continental LDT-465-1A Injection System at 1300 rpm

(R^2 = 0.9760, Root MSE = 1.516)

Variable	Parameter Estimate	Standard Error	t-Statistic
INTERCEP	15.223458	0.628014	24.241
RACK	30.257012	0.470077	64.366
$(VIS)^{-1}$	-10.345716	0.590472	-17.521
Log(VIS)	-2.501337	0.196112	-12.755

TABLE 5. Results of Regression Analysis for Continental LDT-465-1A Injection System at 2600 rpm

(R^2 = 0.9794, Root MSE = 1.314)

Variable	Parameter Estimate	Standard Error	t-Statistic
INTERCEP	15.049560	0.553312	27.500
RACK	23.488275	0.331991	69.747
$(RACK-0.5)^2$	6.656301	1.080741	6.159
$(VIS)^{-1}$	-7.305955	0.509734	-14.333
Log(VIS)	-1.933390	0.172660	-11.198

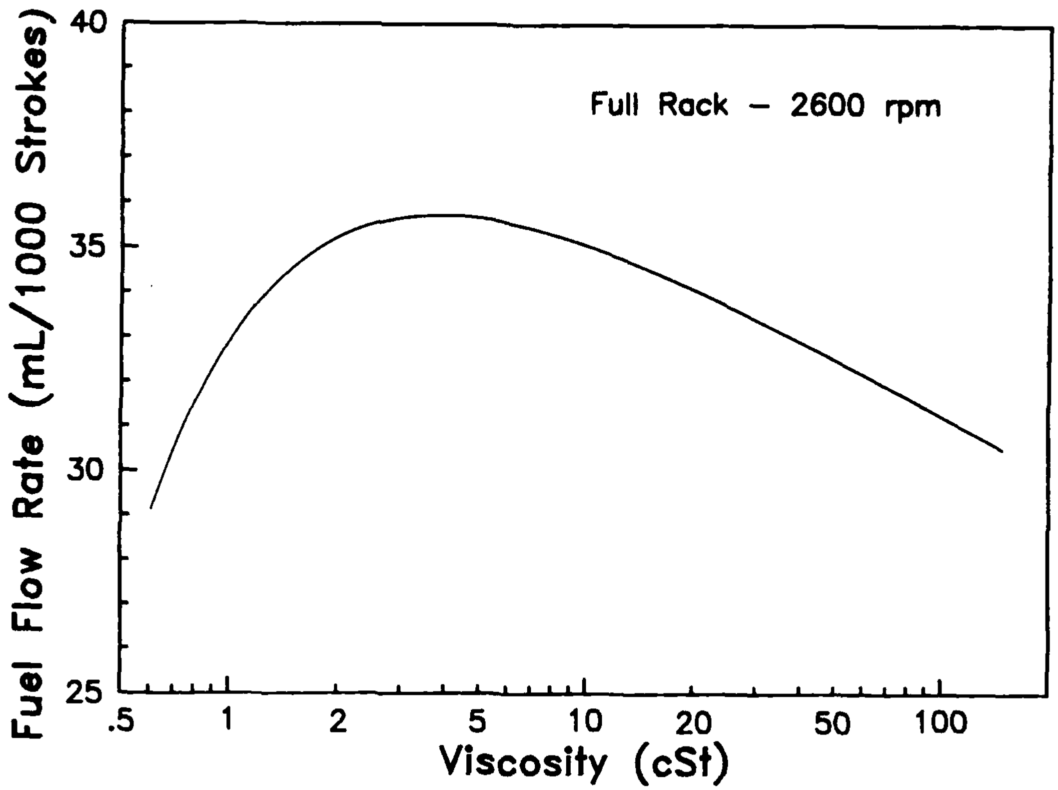

Figure 5. Fuel flow rate versus viscosity for LDT-465-1A

B. Detroit Diesel Allison 6V-53 Injection System

The effect of viscosity on the fuel flow rate for the 6V-53 unit injector was similar to the effect observed for the LDT-465-1A system. The fuel flow rate was found to be linearly proportional to the rack position as illustrated in Fig. 6. The form of the regression equation is illustrated by Eq. (2).

$$FFLW = b_o + b_1 (RACK) + b_2 [\log(VIS)] + b_3 (VIS)^{-1} \quad (2)$$

The results of the regression analysis are shown in TABLE 6. As indicated by the high R^2 value, the fit was good. The effect of viscosity on the fuel flow rate is illustrated in Fig. 7. As shown, the viscosity effect was similar to that observed for the LDT-465-1A system. The decrease in fuel flow rate at the high and low viscosities was attributed to leakage past the barrel and plunger, and pump-filling problems, respectively.

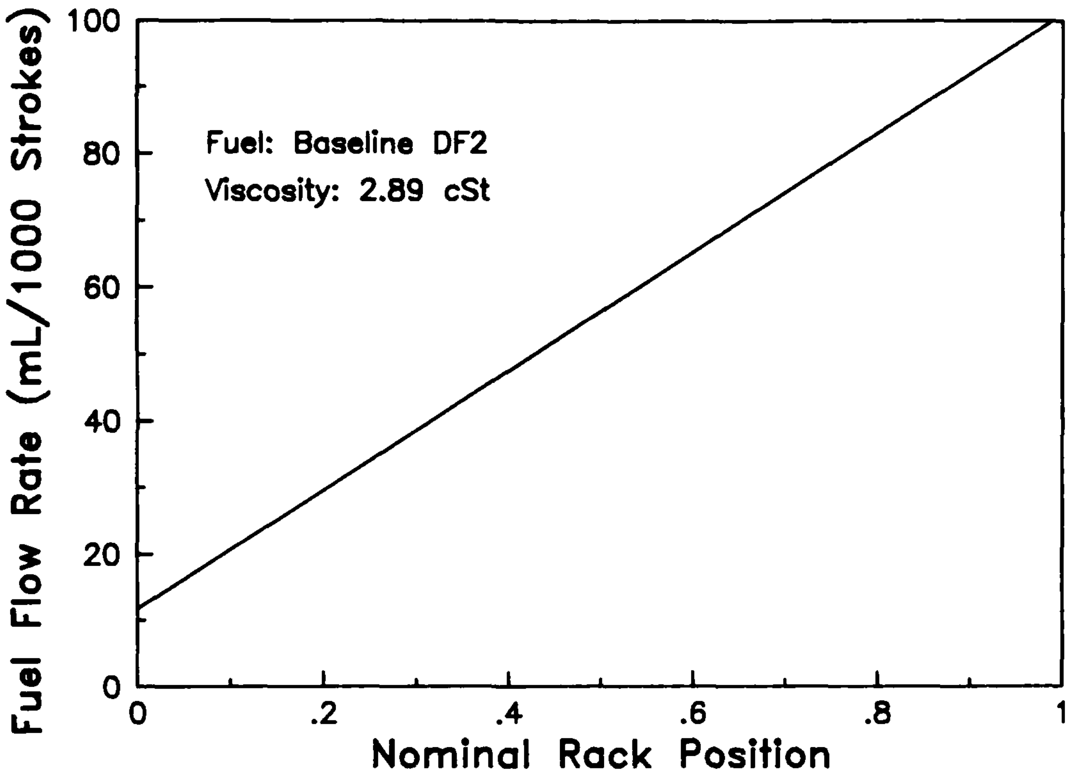

Figure 6. Fuel flow rate versus rack position for DDA 6V-53

TABLE 6. Results of Regression Analysis for Detroit Diesel Allison 6V-53 Injection System

(R^2 = 0.9658, Root MSE = 6.103)

Variable	Parameter Estimate	Standard Error	t-Statistic
INTERCEP	21.387469	2.926351	7.309
RACK	89.140013	1.582619	56.324
Log(VIS)	-4.212652	1.063237	-3.962
$(VIS)^{-1}$	-14.734516	2.455333	-6.001

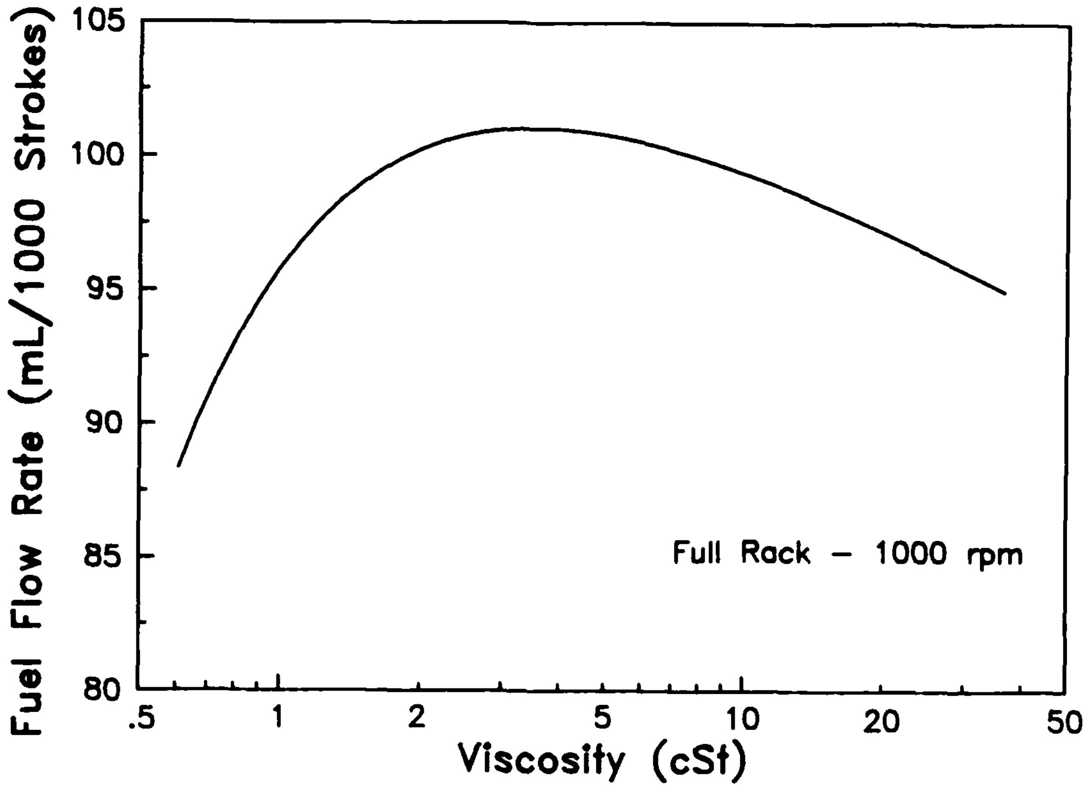

Figure 7. Fuel flow rate versus viscosity for DDA 6V-53

C. Cummins NHC-250 Injection System

The injection system on the NHC-250 engine is a P-T (pressure-time) injector. This system was tested at two speeds and at different fuel pressures. The fuel pressure controlled the fuel flow rate. The form of the regression equation for this injector is illustrated by Eq. (3).

$$FFLW = b_o + b_1 (PRESS)^{1/2} + b_2 (RPM) + b_3 (VIS)^{-1} \qquad (3)$$

where: PRESS = fuel inlet pressure (psi)
RPM = speed (rpm)

The results of the regression analysis are presented in TABLE 7. For the NHC-250 injector, the fuel flow rate was proportional to the square root of the pressure as illustrated in Fig. 8. At the higher speed, less time was available for pump filling. Therefore, the speed term has a negative coefficient, indicating a decrease in flow rate at the higher speeds. Fig. 9 illustrates the effect of viscosity on fuel flow rate. As

TABLE 7. Results of Regression Analysis for Cummins NHC-250 Injection System

(R^2 = 0.9588, Root MSE = 6.33)

Variable	Parameter Estimate	Standard Error	t-Statistic
INTERCEP	132.031	1.815719	72.715
$(PRESS)^{1/2}$	7.145382	0.156595	45.630
RPM	-0.089854	1.660483	-54.113
$(VIS)^{-1}$	13.011490	1.167008	11.149

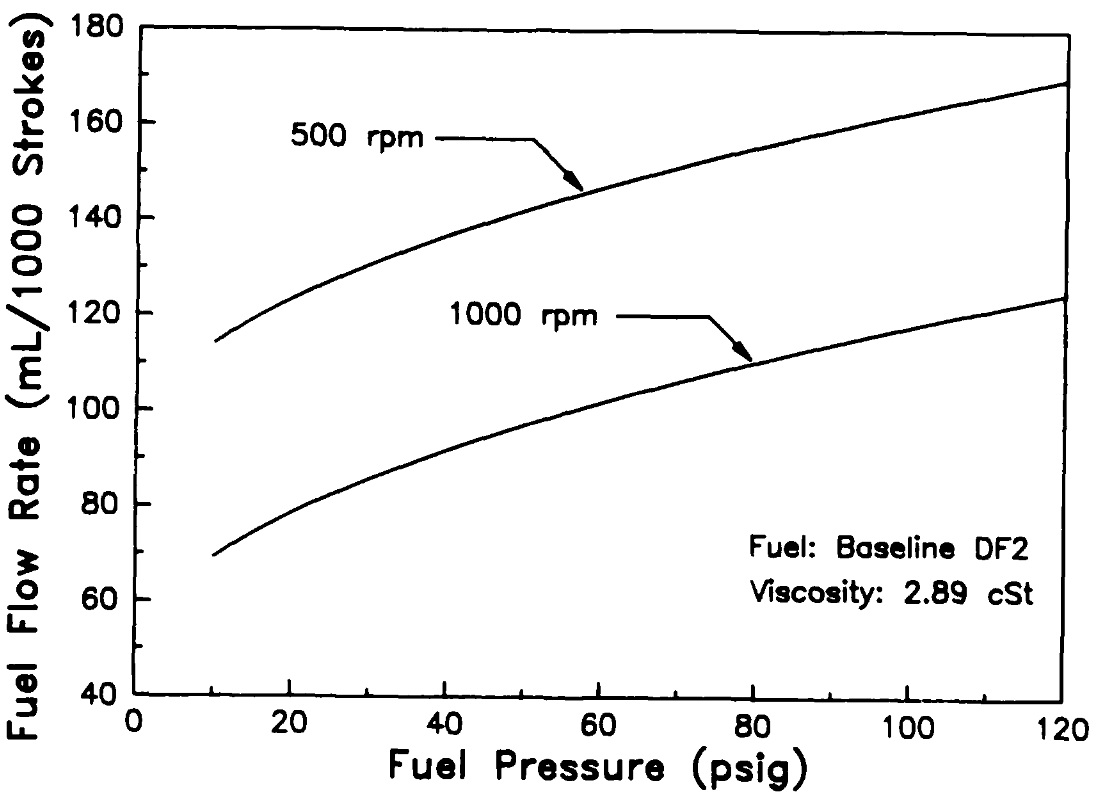

Figure 8. Fuel flow rate versus fuel pressure for NHC-250

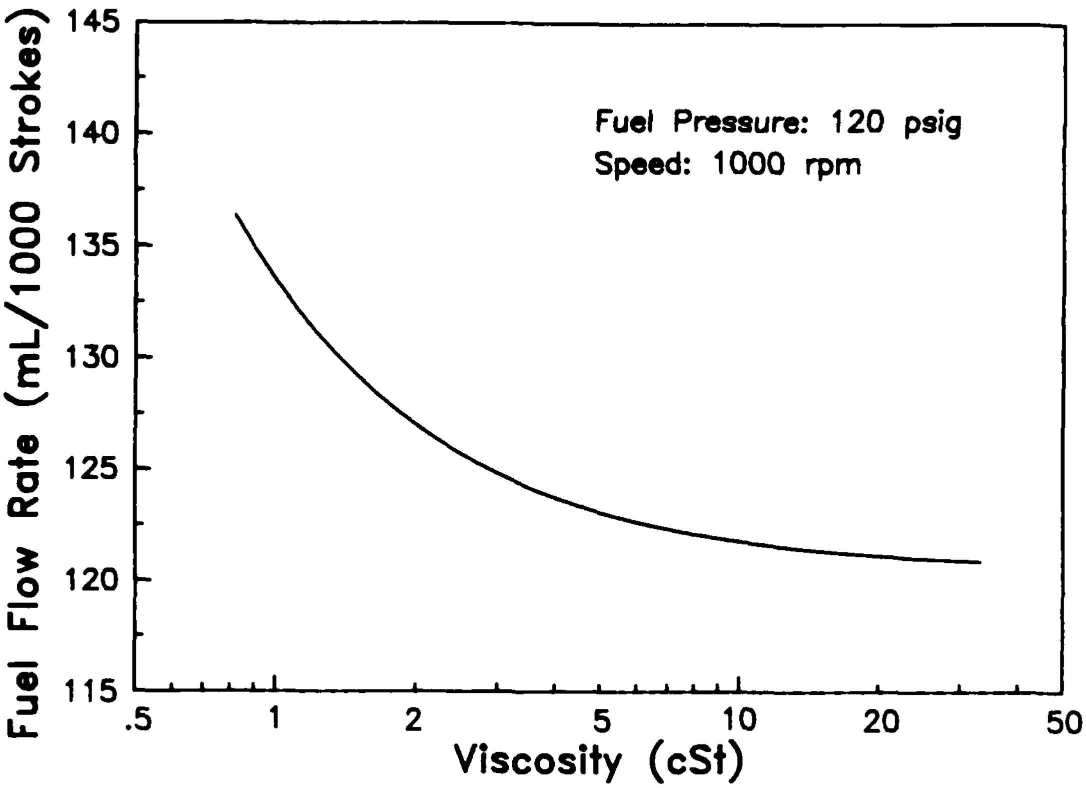

Figure 9. Fuel flow rate versus viscosity for NHC-250

shown in the figure, the flow rate was higher at the lower viscosities. This higher flow rate was attributed to improved pump-filling characteristics at the lower viscosities. Fuel leakage past the plunger was not apparent at the lower viscosities, as was observed with the LDT-465-1A and 6V-53 injector systems. The NHC-250 system was less sensitive than the LDT-465-1A and 6V-53 systems to pump-filling problems at the high viscosities.

VII. CONCLUSIONS

There was no evidence of vapor lock due to front-end volatility effects at the high test temperatures for any of the injection systems tested. Viscosity was observed to affect the fuel flow rate. For the LDT-465-1A and 6V-53 injection systems, fuels with relatively low viscosities tended to leak past the barrel and plunger assemblies, resulting in a decreased fuel flow rate. The fuels with the higher viscosities tended to have problems completely filling the pump in the time available. Thus, use of these fuels also resulted in decreased fuel flow. Leakage did not appear to be a problem with the NHC-

250 injection system. The pump-filling characteristics were related to fuel viscosity. The low viscosity fuels had higher flow rates than the typical DF-2 fuel. Fuels with higher viscosities tended to have lower flow rates than the DF-2 fuel.

The use of emergency or alternative fuels with viscosities significantly different from DF-2 could result in reduced fuel flow rates and a reduction in maximum power output. The loss of power would be more noticeable at high or low ambient temperatures, which would accentuate the problems occurring with high viscosity fuels at low ambient temperatures and low viscosity fuels at high temperatures.

VIII. REFERENCES

1. Data furnished to BFLRF via Belvoir RDE Center from USATACOM on Contract DAAK70-81-C-0209, December 1981.
2. LePera, M.E., "Thermal Oxidative Stability of Automotive Diesel Fuels," Interim Report, U.S. Army Materiel Command, February 1973.

APPENDIX A

FUEL FLOW DATA FOR CONTINENTAL LDT-465-1A INJECTION SYSTEM

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
DF-2	1300	0.08	-2.8	11.10	9.85
DF-2	1300	0.08	-2.2	11.20	9.67
DF-2	1300	0.08	6.7	11.10	6.46
DF-2	1300	0.08	7.8	11.00	6.24
DF-2	1300	0.08	22.8	10.50	4.13
DF-2	1300	0.08	23.9	10.50	4.02
DF-2	1300	0.08	30.0	10.30	3.48
DF-2	1300	0.08	76.1	8.80	1.55
DF-2	1300	0.08	77.2	9.20	1.53
DF-2	1300	0.38	-2.2	22.30	8.67
DF-2	1300	0.38	-1.7	22.10	8.50
DF-2	1300	0.38	6.7	21.30	6.46
DF-2	1300	0.38	8.9	21.20	6.03
DF-2	1300	0.38	22.8	20.80	4.13
DF-2	1300	0.38	23.9	20.80	4.02
DF-2	1300	0.38	30.0	20.80	3.48
DF-2	1300	0.38	75.6	16.60	1.57
DF-2	1300	0.38	77.2	16.70	1.53
DF-2	1300	0.62	-2.2	29.60	8.67
DF-2	1300	0.62	0.0	29.80	8.03
DF-2	1300	0.62	7.2	30.10	6.35
DF-2	1300	0.62	8.3	29.00	6.14
DF-2	1300	0.62	22.2	29.90	4.19
DF-2	1300	0.62	22.8	29.00	4.13
DF-2	1300	0.62	29.4	28.60	3.53
DF-2	1300	0.62	76.7	24.20	1.54
DF-2	1300	0.62	76.7	24.10	1.54
DF-2	1300	0.89	-2.2	38.10	8.67
DF-2	1300	0.89	0.0	39.30	8.03
DF-2	1300	0.89	7.2	33.20	6.35
DF-2	1300	0.89	8.3	38.60	6.14
DF-2	1300	0.89	22.2	37.90	4.19
DF-2	1300	0.89	22.9	39.00	4.13
DF-2	1300	0.89	30.6	36.60	3.44
DF-2	1300	0.89	75.6	33.40	1.57
DF-2	1300	0.89	76.1	33.50	1.55
DF-2	2600	0.00	-2.2	13.50	8.67
DF-2	2600	0.00	-2.2	13.60	8.67
DF-2	2600	0.00	10.6	12.90	5.74
DF-2	2600	0.00	11.1	12.80	5.65
DF-2	2600	0.00	22.8	12.30	4.13
DF-2	2600	0.00	23.3	12.40	4.08
DF-2	2600	0.00	34.4	11.20	3.16
DF-2	2600	0.00	77.2	9.80	1.53
DF-2	2600	0.00	77.8	9.70	1.52
DF-2	2600	0.43	-2.8	23.00	8.85
DF-2	2600	0.43	-2.8	23.00	8.85
DF-2	2600	0.43	11.7	21.30	5.56
DF-2	2600	0.43	11.7	21.20	5.56
DF-2	2600	0.43	22.8	19.50	4.13
DF-2	2600	0.43	22.8	19.40	4.13
DF-2	2600	0.43	33.3	19.10	3.24
DF-2	2600	0.43	76.7	17.60	1.54
DF-2	2600	0.43	77.2	17.40	1.53
DF-2	2600	0.72	-2.8	30.00	8.85
DF-2	2600	0.72	-2.8	30.10	8.85
DF-2	2600	0.72	12.2	29.70	5.47
DF-2	2600	0.72	12.2	29.70	5.47
DF-2	2600	0.72	22.2	28.70	4.19
DF-2	2600	0.72	22.8	28.60	4.13
DF-2	2600	0.72	32.8	27.80	3.28
DF-2	2600	0.72	76.7	26.00	1.54
DF-2	2600	0.72	77.2	26.00	1.53
DF-2	2600	1.00	-2.2	36.60	8.67
DF-2	2600	1.00	0.6	37.10	7.87
DF-2	2600	1.00	12.2	36.40	5.47
DF-2	2600	1.00	12.8	36.70	5.39
DF-2	2600	1.00	22.8	36.40	4.13
DF-2	2600	1.00	22.8	36.60	4.13
DF-2	2600	1.00	31.7	36.00	3.36
DF-2	2600	1.00	75.6	33.10	1.57
DF-2	2600	1.00	77.2	33.20	1.53

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
25% JP-4	1300	0.08	32.2	10.70	2.03
25% JP-4	1300	0.08	60.6	9.00	1.33
25% JP-4	1300	0.08	60.6	8.60	1.33
25% JP-4	1300	0.08	73.9	8.00	1.13
25% JP-4	1300	0.08	73.9	8.30	1.13
25% JP-4	1300	0.38	31.7	18.60	2.05
25% JP-4	1300	0.38	59.4	17.30	1.35
25% JP-4	1300	0.38	61.7	16.70	1.32
25% JP-4	1300	0.38	73.9	15.40	1.13
25% JP-4	1300	0.38	74.4	15.50	1.13
25% JP-4	1300	0.62	30.6	27.60	2.09
25% JP-4	1300	0.62	58.9	23.90	1.36
25% JP-4	1300	0.62	60.6	24.20	1.33
25% JP-4	1300	0.62	72.8	21.30	1.15
25% JP-4	1300	0.62	75.0	22.00	1.12
25% JP-4	1300	0.89	28.9	37.50	2.15
25% JP-4	1300	0.89	57.2	33.40	1.39
25% JP-4	1300	0.89	59.4	33.50	1.35
25% JP-4	1300	0.89	71.1	31.10	1.17
25% JP-4	1300	0.89	72.2	30.80	1.16
25% JP-4	2600	0.00	35.0	9.90	1.94
25% JP-4	2600	0.00	65.0	10.00	1.26
25% JP-4	2600	0.00	67.2	9.90	1.23
25% JP-4	2600	0.00	76.7	9.70	1.10
25% JP-4	2600	0.00	77.8	9.90	1.08
25% JP-4	2600	0.43	35.0	18.60	1.94
25% JP-4	2600	0.43	63.3	17.60	1.29
25% JP-4	2600	0.43	65.6	17.60	1.25
25% JP-4	2600	0.43	77.2	17.20	1.09
25% JP-4	2600	0.43	77.8	17.20	1.08
25% JP-4	2600	0.72	34.4	27.60	1.96
25% JP-4	2600	0.72	62.8	25.60	1.30
25% JP-4	2600	0.72	65.6	25.40	1.25
25% JP-4	2600	0.72	74.4	24.70	1.13
25% JP-4	2600	0.72	76.1	24.70	1.10
25% JP-4	2600	1.00	33.3	36.20	1.99
25% JP-4	2600	1.00	60.0	33.40	1.34
25% JP-4	2600	1.00	65.0	33.30	1.26
25% JP-4	2600	1.00	73.9	32.10	1.13
25% JP-4	2600	1.00	75.0	32.00	1.12
50% JP-4	1300	0.08	31.7	10.10	1.35
50% JP-4	1300	0.08	53.3	8.70	1.03
50% JP-4	1300	0.08	70.0	8.00	0.86
50% JP-4	1300	0.08	71.7	7.50	0.84
50% JP-4	1300	0.38	31.1	18.50	1.36
50% JP-4	1300	0.38	51.7	16.60	1.05
50% JP-4	1300	0.38	67.8	13.80	0.98
50% JP-4	1300	0.38	72.8	13.50	0.83
50% JP-4	1300	0.62	30.6	26.10	1.38
50% JP-4	1300	0.62	50.0	23.50	1.07
50% JP-4	1300	0.62	66.1	20.70	0.89
50% JP-4	1300	0.62	72.8	20.20	0.83
50% JP-4	1300	0.89	30.0	34.40	1.39
50% JP-4	1300	0.89	47.8	32.70	1.10
50% JP-4	1300	0.89	63.3	29.20	0.92
50% JP-4	1300	0.89	68.9	28.40	0.87
50% JP-4	2600	0.00	33.9	11.00	1.31
50% JP-4	2600	0.00	54.4	10.30	1.02
50% JP-4	2600	0.00	72.2	7.90	0.84
50% JP-4	2600	0.00	75.6	7.70	0.81
50% JP-4	2600	0.43	33.3	19.30	1.32
50% JP-4	2600	0.43	53.9	18.00	1.02
50% JP-4	2600	0.43	72.2	16.90	0.84
50% JP-4	2600	0.43	74.4	16.70	0.82
50% JP-4	2600	0.72	32.8	27.60	1.33
50% JP-4	2600	0.72	53.3	25.30	1.03
50% JP-4	2600	0.72	70.6	23.60	0.85
50% JP-4	2600	0.72	73.9	23.30	0.82
50% JP-4	2600	1.00	32.2	35.50	1.34
50% JP-4	2600	1.00	51.1	32.20	1.06
50% JP-4	2600	1.00	68.9	30.80	0.87
50% JP-4	2600	1.00	71.1	30.60	0.85

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
75% JP-4	1300	0.08	33.3	9.50	0.94
75% JP-4	1300	0.08	52.2	8.60	0.76
75% JP-4	1300	0.08	72.2	6.40	0.62
75% JP-4	1300	0.08	72.8	6.20	0.62
75% JP-4	1300	0.38	32.8	17.60	0.95
75% JP-4	1300	0.38	50.6	15.20	0.77
75% JP-4	1300	0.38	70.6	12.30	0.63
75% JP-4	1300	0.38	72.8	12.30	0.62
75% JP-4	1300	0.62	32.8	24.70	0.95
75% JP-4	1300	0.62	48.9	22.10	0.79
75% JP-4	1300	0.62	63.9	18.80	0.67
75% JP-4	1300	0.62	71.7	18.40	0.62
75% JP-4	1300	0.89	32.2	33.00	0.95
75% JP-4	1300	0.89	42.8	30.80	0.84
75% JP-4	1300	0.89	59.4	26.90	0.70
75% JP-4	1300	0.89	68.3	26.10	0.64
75% JP-4	2600	0.00	35.6	10.80	0.92
75% JP-4	2600	0.00	55.6	9.20	0.73
75% JP-4	2600	0.00	70.0	5.50	0.63
75% JP-4	2600	0.00	70.6	5.20	0.63
75% JP-4	2600	0.43	35.0	18.50	0.92
75% JP-4	2600	0.43	54.4	17.50	0.74
75% JP-4	2600	0.43	68.9	16.30	0.64
75% JP-4	2600	0.43	71.1	16.10	0.63
75% JP-4	2600	0.72	33.9	26.10	0.93
75% JP-4	2600	0.72	53.9	23.90	0.75
75% JP-4	2600	0.72	66.1	22.30	0.66
75% JP-4	2600	0.72	66.7	23.50	0.66
75% JP-4	2600	1.00	33.3	34.40	0.94
75% JP-4	2600	1.00	51.7	31.90	0.76
75% JP-4	2600	1.00	64.4	30.10	0.67
75% JP-4	2600	1.00	68.9	30.00	0.64
33% TL-323	1300	0.08	-1.1	9.10	20.08
33% TL-323	1300	0.08	6.7	8.70	14.09
33% TL-323	1300	0.08	20.6	9.40	8.29
33% TL-323	1300	0.38	-1.1	18.70	20.08
33% TL-323	1300	0.38	6.7	19.10	14.09
33% TL-323	1300	0.38	20.0	19.10	8.45
33% TL-323	1300	0.62	-0.6	26.90	19.55
33% TL-323	1300	0.62	6.7	27.40	14.09
33% TL-323	1300	0.62	20.0	27.70	8.45
33% TL-323	1300	0.89	0.6	35.20	18.54
33% TL-323	1300	0.89	6.7	35.20	14.09
33% TL-323	1300	0.89	20.0	35.60	8.45
33% TL-323	2600	0.00	0.0	12.20	19.03
33% TL-323	2600	0.00	7.8	10.10	13.44
33% TL-323	2600	0.00	20.6	10.90	8.29
33% TL-323	2600	0.43	-0.6	18.50	19.55
33% TL-323	2600	0.43	7.8	13.20	13.44
33% TL-323	2600	0.43	20.6	18.70	8.29
33% TL-323	2600	0.72	-1.7	27.20	20.64
33% TL-323	2600	0.72	7.2	27.00	13.76
33% TL-323	2600	0.72	20.0	27.30	8.45
33% TL-323	2600	1.00	-1.7	34.30	20.64
33% TL-323	2600	1.00	7.2	34.10	13.76
33% TL-323	2600	1.00	20.0	34.00	8.45
67% TL-323	1300	0.08	6.1	7.60	42.13
67% TL-323	1300	0.08	21.1	8.10	20.04
67% TL-323	1300	0.38	5.6	16.70	43.47
67% TL-323	1300	0.38	21.1	18.00	20.04
67% TL-323	1300	0.62	5.6	24.70	43.47
67% TL-323	1300	0.62	21.1	26.20	20.04
67% TL-323	1300	0.89	6.1	32.30	42.13
67% TL-323	1300	0.89	21.1	34.10	20.04
67% TL-323	2600	0.00	7.8	11.40	38.43
67% TL-323	2600	0.00	23.3	8.50	18.22
67% TL-323	2600	0.43	7.2	17.80	39.61
67% TL-323	2600	0.43	22.8	17.40	18.65
67% TL-323	2600	0.72	6.7	25.80	40.85
67% TL-323	2600	0.72	22.2	25.50	19.10
67% TL-323	2600	1.00	6.1	32.40	42.13
67% TL-323	2600	1.00	21.7	33.10	19.56

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
DF-2	1300	0.08	-2.8	11.10	9.85
DF-2	1300	0.08	-2.2	11.20	9.67
TL-323	1300	0.08	11.7	4.50	148.96
TL-323	1300	0.08	22.2	5.10	67.15
TL-323	1300	0.38	12.8	13.50	135.90
TL-323	1300	0.38	22.2	14.30	67.15
TL-323	1300	0.62	13.3	21.50	129.91
TL-323	1300	0.62	21.7	22.60	69.76
TL-323	1300	0.89	13.3	29.20	129.91
TL-323	1300	0.89	21.7	32.00	69.76
TL-323	2600	0.00	13.9	9.10	124.24
TL-323	2600	0.00	25.0	8.30	55.84
TL-323	2600	0.43	13.3	15.60	129.91
TL-323	2600	0.43	24.4	16.10	57.90
TL-323	2600	0.72	12.2	22.70	142.25
TL-323	2600	0.72	23.3	20.90	62.31
TL-323	2600	1.00	11.1	28.50	156.07
TL-323	2600	1.00	22.2	30.40	67.15

APPENDIX B

FUEL FLOW DATA FOR DDA 6V-53 INJECTION SYSTEM

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
DF-2	1000	0.00	13.3	9.50	5.30
DF-2	1000	0.00	13.9	9.60	5.22
DF-2	1000	0.00	13.9	10.40	5.22
DF-2	1000	0.00	73.9	7.40	1.60
DF-2	1000	0.00	75.0	7.80	1.58
DF-2	1000	0.25	13.3	35.40	5.30
DF-2	1000	0.25	13.3	36.20	5.30
DF-2	1000	0.25	13.9	36.20	5.22
DF-2	1000	0.25	74.4	27.90	1.59
DF-2	1000	0.25	75.0	31.20	1.58
DF-2	1000	0.25	75.6	32.30	1.57
DF-2	1000	0.50	12.8	55.80	5.39
DF-2	1000	0.50	13.9	59.00	5.22
DF-2	1000	0.50	75.0	58.60	1.58
DF-2	1000	0.50	75.6	56.50	1.57
DF-2	1000	0.50	76.7	58.10	1.54
DF-2	1000	0.75	13.9	84.10	5.22
DF-2	1000	0.75	75.0	84.90	1.58
DF-2	1000	0.75	75.6	86.50	1.57
DF-2	1000	0.75	76.7	91.00	1.54
DF-2	1000	1.00	12.2	99.00	5.47
DF-2	1000	1.00	13.9	96.90	5.22
DF-2	1000	1.00	74.4	100.70	1.59
DF-2	1000	1.00	75.0	104.10	1.58
25% JP-4	1000	0.00	31.7	9.40	2.05
25% JP-4	1000	0.25	31.1	31.40	2.07
25% JP-4	1000	0.50	31.1	57.40	2.07
25% JP-4	1000	0.75	31.1	83.50	2.07
25% JP-4	1000	1.00	31.1	97.40	2.07
50% JP-4	100	0.07	75.6	0.00	0.81
50% JP-4	1000	0.00	68.3	0.00	0.87
50% JP-4	1000	0.00	72.8	0.00	0.83
50% JP-4	1000	0.00	75.6	0.00	0.81
50% JP-4	1000	0.05	73.9	0.00	0.82
50% JP-4	1000	0.05	75.6	3.90	0.81
50% JP-4	1000	0.05	75.6	0.00	0.81
50% JP-4	1000	0.05	76.1	1.90	0.81
50% JP-4	1000	0.07	75.6	5.40	0.81
50% JP-4	1000	0.07	75.6	9.90	0.81
50% JP-4	1000	0.07	75.6	4.90	0.81
50% JP-4	1000	0.09	75.6	6.10	0.81
50% JP-4	1000	0.09	75.6	5.90	0.81
50% JP-4	1000	0.09	75.6	10.30	0.81
50% JP-4	1000	0.09	75.6	9.10	0.81
50% JP-4	1000	0.25	73.9	23.80	0.82
50% JP-4	1000	0.25	75.6	23.80	0.81
50% JP-4	1000	0.25	75.6	26.90	0.81
50% JP-4	1000	0.25	75.6	25.80	0.81
50% JP-4	1000	0.50	75.6	52.30	0.81
50% JP-4	1000	0.50	75.6	52.10	0.81
50% JP-4	1000	0.50	75.6	47.80	0.81
50% JP-4	1000	0.50	76.1	46.90	0.81
50% JP-4	1000	0.75	75.6	70.80	0.81
50% JP-4	1000	0.75	75.6	74.10	0.81
50% JP-4	1000	0.75	76.1	73.00	0.81
50% JP-4	1000	0.75	76.1	64.00	0.81
50% JP-4	1000	1.00	75.6	82.80	0.81
50% JP-4	1000	1.00	76.1	82.20	0.81
75% JP-4	1000	0.00	33.9	7.90	0.93
75% JP-4	1000	0.00	34.4	7.80	0.93
75% JP-4	1000	0.00	68.3	0.00	0.64
75% JP-4	1000	0.00	69.4	2.90	0.64
75% JP-4	1000	0.00	75.6	0.00	0.60
75% JP-4	1000	0.00	75.6	0.00	0.60
75% JP-4	1000	0.00	75.6	0.00	0.60
75% JP-4	1000	0.03	53.9	0.00	0.75
75% JP-4	1000	0.05	56.1	0.00	0.73
75% JP-4	1000	0.06	53.3	4.70	0.75
75% JP-4	1000	0.07	53.3	3.30	0.75
75% JP-4	1000	0.09	55.6	4.90	0.73
75% JP-4	1000	0.14	68.9	17.50	0.64

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
75% JP-4	1000	0.25	33.9	33.80	0.93
75% JP-4	1000	0.25	33.9	33.80	0.93
75% JP-4	1000	0.25	34.4	33.80	0.93
75% JP-4	1000	0.25	69.4	27.30	0.64
75% JP-4	1000	0.25	75.6	26.10	0.60
75% JP-4	1000	0.25	75.6	24.80	0.60
75% JP-4	1000	0.25	75.6	24.80	0.60
75% JP-4	1000	0.50	33.9	58.10	0.93
75% JP-4	1000	0.50	33.9	57.90	0.93
75% JP-4	1000	0.50	34.4	77.50	0.93
75% JP-4	1000	0.50	75.6	45.50	0.60
75% JP-4	1000	0.50	75.6	49.70	0.60
75% JP-4	1000	0.50	76.1	50.00	0.60
75% JP-4	1000	0.75	33.9	81.50	0.93
75% JP-4	1000	0.75	33.9	81.20	0.93
75% JP-4	1000	0.75	34.4	81.10	0.93
75% JP-4	1000	0.75	75.6	70.10	0.60
75% JP-4	1000	0.75	75.6	65.90	0.60
75% JP-4	1000	0.75	75.6	69.70	0.60
75% JP-4	1000	1.00	33.3	95.00	0.94
75% JP-4	1000	1.00	34.4	95.30	0.93
75% JP-4	1000	1.00	74.4	88.70	0.61
75% JP-4	1000	1.00	75.6	79.60	0.60
75% JP-4	1000	1.00	75.6	79.60	0.60
33% TL-323	500	17.18	16.7	110.00	9.50
33% TL-323	500	17.18	17.2	112.80	9.32
33% TL-323	500	44.45	16.1	120.50	9.70
33% TL-323	500	44.45	16.7	121.20	9.50
33% TL-323	500	89.91	16.7	131.10	9.50
33% TL-323	500	89.91	16.7	131.00	9.50
33% TL-323	500	135.36	17.2	143.20	9.32
33% TL-323	500	135.36	17.2	142.80	9.32
33% TL-323	500	180.82	17.8	155.10	9.13
33% TL-323	500	180.82	19.3	153.40	8.95
33% TL-323	500	217.18	13.3	162.60	8.95
33% TL-323	500	217.18	18.3	160.70	8.95
33% TL-323	1000	0.00	18.9	9.20	8.78
33% TL-323	1000	0.00	20.0	8.40	8.45
33% TL-323	1000	0.25	18.9	33.40	8.78
33% TL-323	1000	0.25	20.6	33.40	8.29
33% TL-323	1000	0.50	19.3	54.10	8.95
33% TL-323	1000	0.50	20.0	51.40	8.45
33% TL-323	1000	0.75	18.9	79.80	8.78
33% TL-323	1000	0.75	19.4	69.80	8.61
33% TL-323	1000	1.00	18.9	82.50	8.78
33% TL-323	1000	1.00	18.9	84.80	8.78
33% TL-323	1000	35.36	17.2	76.50	9.32
33% TL-323	1000	35.36	21.1	75.80	8.13
33% TL-323	1000	44.45	17.2	82.80	9.32
33% TL-323	1000	89.91	17.2	96.00	9.32
33% TL-323	1000	89.91	19.4	94.60	8.61
33% TL-323	1000	135.36	16.1	108.70	9.70
33% TL-323	1000	135.36	18.3	109.30	8.95
33% TL-323	1000	180.82	16.1	121.00	9.70
33% TL-323	1000	180.82	16.1	119.90	9.70
33% TL-323	1000	217.18	16.1	126.10	9.70
33% TL-323	1000	217.18	17.2	129.80	9.32
67% TL-323	500	17.18	25.0	110.50	17.00
67% TL-323	500	17.18	27.2	118.80	15.54
67% TL-323	500	44.45	25.0	124.20	17.00
67% TL-323	500	44.45	27.8	150.20	15.20
67% TL-323	500	89.91	23.9	128.70	17.80
67% TL-323	500	89.91	28.3	133.80	14.87
67% TL-323	500	135.36	25.0	142.70	17.00
67% TL-323	500	135.36	29.4	142.80	14.24
67% TL-323	500	180.82	25.6	151.70	16.61
67% TL-323	500	180.82	30.0	153.10	13.94
67% TL-323	500	217.19	26.1	161.60	16.24
67% TL-323	500	217.18	30.6	162.60	13.65

FUEL	RPM	NOMINAL RACK	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
67% TL-323	1000	0.00	25.6	10.30	16.61
67% TL-323	1000	0.00	26.1	10.00	16.24
67% TL-323	1000	0.25	25.0	33.90	17.00
67% TL-323	1000	0.25	26.1	33.80	16.24
67% TL-323	1000	0.50	25.6	57.10	16.61
67% TL-323	1000	0.50	26.1	54.10	16.24
67% TL-323	1000	0.75	25.6	77.30	16.61
67% TL-323	1000	0.75	25.6	78.70	16.61
67% TL-323	1000	1.00	25.6	86.80	16.61
67% TL-323	1000	1.00	26.1	86.50	16.24
67% TL-323	1000	17.18	25.6	64.30	16.61
67% TL-323	1000	17.18	27.2	65.10	15.54
67% TL-323	1000	44.45	25.6	89.90	16.61
67% TL-323	1000	44.45	28.9	87.50	14.55
67% TL-323	1000	89.91	25.6	93.00	16.61
67% TL-323	1000	89.91	28.9	101.30	14.55
67% TL-323	1000	135.36	29.4	110.80	14.24
67% TL-323	1000	135.36	30.0	113.40	13.94
67% TL-323	1000	180.82	28.3	118.70	14.87
67% TL-323	1000	180.82	32.2	120.00	12.83
67% TL-323	1000	217.18	28.9	127.90	14.55
67% TL-323	1000	217.18	33.9	125.50	12.07
TL-323	1000	0.00	31.1	9.90	38.40
TL-323	1000	0.00	32.2	9.60	36.03
TL-323	1000	0.25	30.6	32.20	39.67
TL-323	1000	0.25	32.2	32.30	36.03
TL-323	1000	0.50	30.6	50.40	39.67
TL-323	1000	0.50	32.8	52.30	34.92
TL-323	1000	0.75	31.1	87.00	38.40
TL-323	1000	0.75	32.8	82.70	34.92
TL-323	1000	1.00	31.1	87.10	38.40
TL-323	1000	1.00	31.7	83.30	37.19

APPENDIX C

FUEL FLOW DATA FOR CUMMINS NHC-250 INJECTION SYSTEM

FUEL	RPM	FUEL PRESSURE (PSIG)	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
DF-2	500	10.00	57.8	104.10	2.04
DF-2	500	10.00	58.3	103.60	2.03
DF-2	500	10.00	60.6	104.40	1.95
DF-2	500	14.00	12.2	113.50	5.47
DF-2	500	14.00	15.0	109.40	5.06
DF-2	500	16.00	13.3	114.50	5.30
DF-2	500	25.00	11.1	114.10	5.65
DF-2	500	25.00	11.1	119.20	5.65
DF-2	500	25.00	15.0	121.90	5.06
DF-2	500	25.00	59.4	115.80	1.99
DF-2	500	25.00	62.8	123.50	1.89
DF-2	500	25.00	66.1	115.50	1.79
DF-2	500	50.00	6.7	129.30	6.46
DF-2	500	50.00	10.0	130.50	5.84
DF-2	500	50.00	15.0	142.40	5.06
DF-2	500	50.00	66.1	137.70	1.79
DF-2	500	50.00	67.8	139.70	1.75
DF-2	500	50.00	70.0	139.00	1.69
DF-2	500	75.00	6.1	159.80	6.57
DF-2	500	75.00	9.4	140.50	5.93
DF-2	500	75.00	16.1	152.50	4.91
DF-2	500	75.00	70.6	153.10	1.68
DF-2	500	75.00	71.7	154.50	1.65
DF-2	500	75.00	73.3	150.60	1.62
DF-2	500	100.00	6.1	159.80	6.57
DF-2	500	100.00	9.4	157.70	5.93
DF-2	500	100.00	18.3	167.60	4.63
DF-2	500	100.00	73.9	170.60	1.60
DF-2	500	100.00	75.0	168.10	1.58
DF-2	500	100.00	75.6	165.90	1.57
DF-2	500	120.00	5.6	164.50	6.69
DF-2	500	120.00	8.3	160.70	6.14
DF-2	500	120.00	18.3	178.30	4.63
DF-2	500	120.00	73.9	171.40	1.60
DF-2	500	120.00	76.1	179.10	1.55
DF-2	500	120.00	77.8	173.80	1.52
DF-2	1000	10.00	54.4	77.20	2.16
DF-2	1000	10.00	55.0	77.50	2.14
DF-2	1000	10.00	55.6	77.60	2.12
DF-2	1000	14.00	12.2	80.80	5.47
DF-2	1000	16.00	12.2	62.50	5.47
DF-2	1000	25.00	11.1	81.70	5.65
DF-2	1000	25.00	12.2	85.40	5.47
DF-2	1000	25.00	13.3	86.60	5.30
DF-2	1000	25.00	57.2	82.50	2.06
DF-2	1000	25.00	57.8	85.30	2.04
DF-2	1000	25.00	58.3	82.90	2.03
DF-2	1000	50.00	11.7	103.80	5.56
DF-2	1000	50.00	12.2	101.50	5.47
DF-2	1000	50.00	62.2	103.40	1.90
DF-2	1000	50.00	63.3	100.20	1.87
DF-2	1000	50.00	63.9	100.80	1.86
DF-2	1000	75.00	11.7	110.70	5.56
DF-2	1000	75.00	13.3	113.60	5.30
DF-2	1000	75.00	67.2	107.60	1.76
DF-2	1000	75.00	67.2	108.10	1.76
DF-2	1000	75.00	68.9	106.80	1.72
DF-2	1000	100.00	12.2	111.30	5.47
DF-2	1000	100.00	14.4	120.00	5.14
DF-2	1000	100.00	71.1	111.80	1.67
DF-2	1000	100.00	72.2	112.90	1.64
DF-2	1000	100.00	72.8	114.70	1.63
DF-2	1000	120.00	13.3	120.50	5.30
DF-2	1000	120.00	16.7	122.10	4.84
DF-2	1000	120.00	74.4	119.00	1.59
DF-2	1000	120.00	75.0	119.10	1.58
DF-2	1000	120.00	75.6	119.10	1.57

FUEL	RPM	SAS FUEL PRESSURE (PSIG)	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
25% JP-4	500	10.00	28.3	115.80	2.17
25% JP-4	500	10.00	29.4	112.20	2.13
25% JP-4	500	10.00	31.1	113.00	2.07
25% JP-4	500	10.00	56.7	118.60	1.40
25% JP-4	500	10.00	57.8	119.70	1.38
25% JP-4	500	10.00	60.0	116.70	1.34
25% JP-4	500	25.00	29.4	129.80	2.13
25% JP-4	500	25.00	30.0	121.60	2.11
25% JP-4	500	25.00	31.7	119.90	2.05
25% JP-4	500	25.00	60.6	131.70	1.33
25% JP-4	500	25.00	61.7	134.80	1.32
25% JP-4	500	25.00	65.0	134.50	1.26
25% JP-4	500	50.00	31.1	151.00	2.07
25% JP-4	500	50.00	32.8	145.10	2.01
25% JP-4	500	50.00	32.8	149.20	2.01
25% JP-4	500	50.00	65.0	157.10	1.26
25% JP-4	500	50.00	65.6	149.40	1.25
25% JP-4	500	50.00	67.8	150.60	1.22
25% JP-4	500	50.00	68.3	156.00	1.21
25% JP-4	500	75.00	32.8	163.60	2.01
25% JP-4	500	75.00	35.0	166.60	1.94
25% JP-4	500	75.00	36.1	162.60	1.90
25% JP-4	500	75.00	66.7	165.60	1.24
25% JP-4	500	75.00	70.0	156.90	1.19
25% JP-4	500	75.00	73.3	158.60	1.14
25% JP-4	500	100.00	34.4	177.40	1.96
25% JP-4	500	100.00	36.7	178.50	1.88
25% JP-4	500	100.00	37.8	178.50	1.85
25% JP-4	500	100.00	70.0	168.70	1.19
25% JP-4	500	100.00	74.4	167.90	1.13
25% JP-4	500	100.00	75.0	174.30	1.12
25% JP-4	500	120.00	35.0	175.30	1.94
25% JP-4	500	120.00	37.2	183.60	1.87
25% JP-4	500	120.00	38.3	185.80	1.84
25% JP-4	500	120.00	71.1	178.30	1.17
25% JP-4	500	120.00	74.4	173.60	1.13
25% JP-4	500	120.00	76.1	179.40	1.10
25% JP-4	1000	10.00	27.2	78.00	2.22
25% JP-4	1000	10.00	28.9	78.20	2.15
25% JP-4	1000	10.00	31.1	79.20	2.07
25% JP-4	1000	10.00	50.0	74.60	1.54
25% JP-4	1000	10.00	53.3	73.60	1.47
25% JP-4	1000	10.00	57.8	74.20	1.38
25% JP-4	1000	14.00	14.4	81.50	2.84
25% JP-4	1000	25.00	27.2	88.10	2.22
25% JP-4	1000	25.00	28.9	86.20	2.15
25% JP-4	1000	25.00	30.6	83.60	2.09
25% JP-4	1000	25.00	51.1	81.90	1.52
25% JP-4	1000	25.00	53.3	85.10	1.47
25% JP-4	1000	25.00	57.2	81.90	1.39
25% JP-4	1000	50.00	28.3	107.30	2.17
25% JP-4	1000	50.00	29.4	105.70	2.13
25% JP-4	1000	50.00	31.1	100.01	2.07
25% JP-4	1000	50.00	56.7	104.40	1.40
25% JP-4	1000	50.00	58.3	101.80	1.37
25% JP-4	1000	50.00	61.1	103.40	1.32
25% JP-4	1000	75.00	31.1	114.20	2.07
25% JP-4	1000	75.00	31.7	112.00	2.05
25% JP-4	1000	75.00	33.3	109.10	1.99
25% JP-4	1000	75.00	63.3	108.30	1.29
25% JP-4	1000	75.00	63.3	111.10	1.29
25% JP-4	1000	75.00	66.1	109.30	1.24
25% JP-4	1000	100.00	33.3	118.50	1.99
25% JP-4	1000	100.00	33.9	116.80	1.97
25% JP-4	1000	100.00	35.0	115.50	1.94
25% JP-4	1000	100.00	66.1	117.10	1.24
25% JP-4	1000	100.00	71.1	116.20	1.17
25% JP-4	1000	100.00	71.1	118.90	1.17
25% JP-4	1000	120.00	36.1	123.30	1.90
25% JP-4	1000	120.00	36.1	122.10	1.90
25% JP-4	1000	120.00	37.8	120.10	1.85
25% JP-4	1000	120.00	68.3	122.60	1.21
25% JP-4	1000	120.00	73.9	126.70	1.13
25% JP-4	1000	120.00	74.4	125.50	1.13

FUEL	RPM	FUEL PRESSURE (PSIG)	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
50% JP-4	500	10.00	51.7	125.00	1.05
50% JP-4	500	10.00	53.9	120.40	1.02
50% JP-4	500	10.00	55.6	125.00	1.00
50% JP-4	500	25.00	57.8	138.70	0.98
50% JP-4	500	25.00	61.1	135.20	0.94
50% JP-4	500	25.00	64.4	136.10	0.91
50% JP-4	500	50.00	66.1	158.80	0.89
50% JP-4	500	50.00	66.1	158.60	0.89
50% JP-4	500	50.00	67.8	156.60	0.88
50% JP-4	500	75.00	68.3	171.90	0.87
50% JP-4	500	75.00	71.1	171.00	0.85
50% JP-4	500	75.00	71.1	169.80	0.85
50% JP-4	500	100.00	71.1	184.10	0.85
50% JP-4	500	100.00	73.9	184.90	0.82
50% JP-4	500	100.00	74.4	180.00	0.82
50% JP-4	500	120.00	72.8	192.00	0.83
50% JP-4	500	120.00	74.4	184.30	0.82
50% JP-4	500	120.00	75.6	189.20	0.81
50% JP-4	1000	10.00	48.9	78.10	1.08
50% JP-4	1000	10.00	49.4	76.30	1.08
50% JP-4	1000	10.00	52.2	73.90	1.04
50% JP-4	1000	25.00	50.6	88.50	1.06
50% JP-4	1000	25.00	50.6	87.10	1.06
50% JP-4	1000	25.00	55.0	89.00	1.01
50% JP-4	1000	50.00	56.1	107.70	1.00
50% JP-4	1000	50.00	57.9	[illegible]	0.98
50% JP-4	1000	50.00	59.4	107.70	0.96
50% JP-4	1000	75.00	61.1	117.20	0.94
50% JP-4	1000	75.00	65.6	112.80	0.90
50% JP-4	1000	75.00	68.9	113.00	0.87
50% JP-4	1000	100.00	66.7	125.50	0.89
50% JP-4	1000	100.00	68.3	123.90	0.87
50% JP-4	1000	100.00	72.8	123.80	0.83
50% JP-4	1000	120.00	69.4	132.50	0.86
50% JP-4	1000	120.00	71.7	131.70	0.84
50% JP-4	1000	120.00	76.7	131.80	0.80
33% TL-323	500	10.00	16.7	110.00	9.50
33% TL-323	500	10.00	17.2	112.90	9.32
33% TL-323	500	25.00	16.1	120.50	9.70
33% TL-323	500	25.00	16.7	121.20	9.50
33% TL-323	500	50.00	16.7	131.10	9.50
33% TL-323	500	50.00	16.7	131.00	9.50
33% TL-323	500	75.00	17.2	141.20	9.32
33% TL-323	500	75.00	17.2	142.80	9.32
33% TL-323	500	100.00	17.8	155.10	9.13
33% TL-323	500	100.00	19.3	153.40	8.95
33% TL-323	500	120.00	18.3	162.60	8.95
33% TL-323	500	120.00	18.3	160.70	8.95
33% TL-323	1000	20.00	17.2	76.50	9.32
33% TL-323	1000	20.00	21.1	75.80	9.13
33% TL-323	1000	25.00	17.2	82.80	9.32
33% TL-323	1000	25.00	20.0	81.10	8.45
33% TL-323	1000	50.00	17.2	96.00	9.32
33% TL-323	1000	50.00	19.4	94.60	8.61
33% TL-323	1000	75.00	16.1	108.70	9.70
33% TL-323	1000	75.00	18.3	109.30	8.95
33% TL-323	1000	100.00	16.1	121.00	9.70
33% TL-323	1000	100.00	16.1	119.40	9.70
33% TL-323	1000	120.00	16.1	126.10	9.70
33% TL-323	1000	120.00	17.2	129.80	9.32
67% TL-323	500	10.00	25.0	110.50	17.00
67% TL-323	500	10.00	27.2	118.80	15.54
67% TL-323	500	25.00	[illegible]	124.20	17.00
67% TL-323	500	25.00	27.8	150.20	15.20
67% TL-323	500	50.00	23.9	128.70	17.80
67% TL-323	500	50.00	28.3	133.80	14.87
67% TL-323	500	75.00	25.0	142.70	17.00
67% TL-323	500	75.00	29.4	142.80	14.24
67% TL-323	500	100.00	25.6	151.70	16.61
67% TL-323	500	100.00	30.0	153.10	13.94
67% TL 323	500	120.00	26.1	161.60	16.24
67% TL-323	500	120.00	30.6	162.60	13.65

FUEL	RPM	FUEL PRESSURE (PSIG)	FUEL TEMP (°C)	FUEL FLOW (mL/1000STROKES)	VISCOSITY (cSt)
67% TL-323	1000	10.00	25.6	64.30	16.61
67% TL-323	1000	10.00	27.2	65.10	15.54
67% TL-323	1000	25.00	25.6	89.90	16.61
67% TL-323	1000	25.00	28.9	87.50	14.55
67% TL-323	1000	50.00	25.6	93.00	16.61
67% TL-323	1000	50.00	28.9	101.30	14.55
67% TL-323	1000	75.00	29.4	110.80	14.28
67% TL-323	1000	75.00	30.0	113.40	13.94
67% TL-323	1000	100.00	28.3	118.70	14.87
67% TL-323	1000	100.00	32.2	120.00	12.83
67% TL-323	1000	120.00	28.9	127.90	14.55
67% TL-323	1000	120.00	33.9	125.50	12.07
TL-323	500	20.00	35.0	118.90	30.89
TL-323	500	40.00	36.7	137.80	28.26
TL-323	500	60.00	37.8	157.90	26.67
TL-323	500	80.00	36.1	156.20	29.10
TL-323	1000	20.00	33.3	63.20	33.85
TL-323	1000	40.00	33.9	85.00	32.82
TL-323	1000	60.00	35.6	92.70	29.98
TL-323	1000	80.00	38.9	110.30	25.20

DEPARTMENT OF DEFENSE

DEFENSE TECHNICAL INFORMATION CTR
CAMERON STATION 12
ALEXANDRIA VA 22314

DEPT. OF DEFENSE
ATTN: OASD/A&L (EP) (MR DYCKMAN) 1
WASHINGTON DC 20301-8000

CDR
DEFENSE FUEL SUPPLY CTR
ATTN: DFSC-Q (MR MARTIN) 1
DFSC-DF (MR FRENCH) 1
CAMERON STATION
ALEXANDRIA VA 22304-6160

DOD
ATTN: DUSDRE (RAT) (DR DIX) 1
ATTN: ROOM 3-D-1089, PENTAGON 1
WASHINGTON DC 20301

DEFENSE ADVANCED RES PROJ AGENCY
DEFENSE SCIENCES OFC 1
1400 WILSON BLVD
ARLINGTON VA 22209

DEPARTMENT OF THE ARMY

CDR
U.S. ARMY BELVOIR RESEARCH, DEVELOPMENT & ENGINEERING CTR
ATTN: STRBE-VF 10
STRBE-BT 2
FORT BELVOIR VA 22060-5606

HG, DEPT OF ARMY
ATTN: DALO-TSE (COL BLISS) 1
DALO-TSZ-B (MR KOWALCZYK) 1
DAMA-ARZ (DR CHURCH) 1
DAMA-ART (MR APPEL) 1
WASHINGTON DC 20310-0005

CDR
US ARMY MATERIEL COMMAND
ATTN: AMCDE-SS 1
AMCSM-WST 1
5001 EISENHOWER AVE
ALEXANDRIA VA 22333-0001

CDR
US ARMY TANK-AUTOMOTIVE CMD
ATTN: AMSTA-RG (MR WHEELOCK) 1
AMSTA-TSL (MR BURG) 1
AMSTA-MTC (MR GAGLIO), AMSTA-MC, AMSTA-MV 1
AMSTA-RGP (MR RAGGIO/ MR McCARTNEY) 1
AMSTA-MLF (MR KELLER) 1
WARREN MI 48397-5000

DIRECTOR
US ARMY AVIATION RESEARCH & TECHNOLOGY ACTIVITIES (AVSCOM)
ATTN: SAURT-R (MR ANDRE) 1
AMES RESEARCH CENTER (MAIL STOP 207-5)
MOFFETT FIELD CA 94035-1099

DIRECTOR
US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
ATTN: AMXSY-CM (MR NIEMEYER) 1
ABERDEEN PROVING GROUND MD 21005-5006

DIRECTOR
APPLIED TECHNOLOGY DIRECTORATE
U.S. ARMY R&T ACTIVITIES (AVSCOM)
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SAVDL-ATL-ASV 1
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HQ, 172D INFANTRY BRIGADE (ALASKA)
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DIRECTORATE OF INDUSTRIAL OPERATIONS
FORT RICHARDSON AK 99505

CDR
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STRGP-FE, BLDG 85-3 (MR GARY SMITH) 1
STRGP-FT (MR FOSTER) 1
NEW CUMBERLAND PA 17070-5008

CDR
US ARMY COLD REGION TEST CENTER
ATTN: STECR-TA 1
APO SEATTLE 98733

CDR
US ARMY LABORATORY COMMAND
ATTN: AMSLC-TP-PB (DR GONANO) 1
AMSLC-TP-AL (LTC SCHRADER) 1
ADELPHIA MD 20783-1145

CDR
US ARMY RES & STDZN GROUP (EUROPE)
ATTN: AMXSN-UK-RA (DR OERTEL) 1
BOX 65
FPO NEW YORK 09510

PROJECT MGR, M113 FAMILY OF VEHICLES
ATTN: AMCPM-M113-T 1
WARREN MI 48397

CDR, US ARMY AVIATION SYSTEMS CMD
ATTN: AMSAV-EP (MR EDWARDS) 1
AMSAV-NS 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
US ARMY FORCES COMMAND
ATTN: AFLG-REG 1
AFLG-POP 1
FORT MCPHERSON GA 30330

CDR
US ARMY YUMA PROVING GROUND
ATTN: STEYP-MT-TL-M (MR DOEBBLER) 1
YUMA AZ 85364-9103

PROJ MGR, BRADLEY FIGHTING VEHICLE SYS
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CDR
US ARMY DEVELOPMENT AND EMPLOYMENT AGENCY
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FT LEWIS VA 98433-5000

PROJ MGR, MOBILE ELECTRIC POWER
ATTN: AMCPM-MEP-TM 1
7500 BACKLICK ROAD
SPRINGFIELD VA 22150

PROJ OFF, AMPHIBIOUS AND WATER CRAFT
ATTN: AMCPM-AWC-R 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120

CDR
US ARMY EUROPE & SEVENTH ARMY
ATTN: AEAGG-FMD 1
AEAGD-TE 1
APO NY 09403

CDR
US ARMY RESEARCH OFC
ATTN: SLCRO-EG (DR MANN) 1
SLCRO-CB 1
P O BOX 12211
RSCH TRIANGLE PARK NC 27709-2211

PROG MGR, TACTICAL VEHICLE
ATTN: AMCPM-TV 1
WARREN MI 48397

CDR
TRADOC COMBINED ARMS TEST ACTIVITY
ATTN: ATCT-CA 1
FORT HOOD TX 76544

CDR
US ARMY DEPOT SYSTEMS CMD
ATTN: AMSDS-RM-EFO 1
CHAMBERSBURG PA 17201

HQ, EUROPEAN COMMAND
ATTN: J4/7-LJPO (LTC McCURRY) 1
VAIHINGEN, GE
APO NY 09128

CDR
US ARMY GENERAL MATERIAL & PETROLEUM ACTIVITY
ATTN: STRGP-PW (MR PRICE) 1
BLDG 247, DEFENSE DEPOT TRACY
TRACY CA 95376-5051

PROJ MGR, LIGHT ARMORED VEHICLES
ATTN: AMCPM-LA-E 1
WARREN MI 48397

CDR
US ARMY FOREIGN SCIENCE & TECH CENTER
ATTN: AIAST-RA-ST3 (MR BUSI) 1
AIAST-MT-1 1
FEDERAL BLDG
CHARLOTTESVILLE VA 22901

PROJECT MANAGER, LIGHT COMBAT VEHICLES
ATTN: AMCPM-LCV-TC 1
WARREN, MI 48397

HQ, US ARMY T&E COMMAND
ATTN: AMSTE-TO-O 1
AMSTE-CM-R-O 1
AMSTE-TE-T (MR RITONDO) 1
ABERDEEN PROVING GROUND MD
21005-5006

CDR, US ARMY TROOP SUPPORT COMMAND
ATTN: AMSTR-ME 1
AMSTR-S 1
AMSTR-E 1
AMSTR-WL (MR BRADLEY) 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
CONSTRUCTION ENG RSCH LAB
ATTN: CERL-EM 1
CERL-ES (MR CASE) 1
CERL-EH 1
P O BOX 4005
CHAMPAIGN IL 61820

TRADOC LIAISON OFFICE
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4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
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ATTN: ATSM-CD 1
ATSM-TD 1
ATSM-PFS (MR ELLIOTT) 1
FORT LEE VA 23801

HQ
US ARMY TRAINING & DOCTRINE CMD
ATTN: ATCD-SL-5 1
FORT MONROE VA 23651-5000

CDR
US ARMY NATICK RES & DEV CENTER
ATTN: STRNA-YE (DR KAPLAN) 1
STRNA-U 1
NATICK MA 01760-5000

DIRECTOR
US ARMY RSCH & TECH ACTIVITIES (AVSCOM)
PROPULSION DIRECTORATE
ATTN: SAVDL-PL-D (MR ACURIO) 1
21000 BROOKPARK ROAD
CLEVELAND OH 44135-3127

PROJ MGR, PATRIOT PROJ OFFICE
ATTN: AMCPM-MD-T-C 1
U.S. ARMY MISSILE COMMAND
REDSTONE ARSENAL AL 35898

HQ, US ARMY ARMOR CENTER AND FORT KNOX
ATTN: ATSB-CD 1
FORT KNOX KY 40121

CDR
101ST AIRBORNE DIV (AASLT)
ATTN: AFZB-KE-J 1
AFSB-KE-DMMC 1
FORT CAMPBELL KY 42223

CDR
COMBINED ARMS COMBAT DEVELOPMENT ACTIVITY
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ATZL-CAT-A 1
FORT LEAVENWORTH KS 66027-5300

CDR
US ARMY LOGISTICS CTR
ATTN: ATCL-MS (MR A MARSHALL) 1
ATCL-C 1
FORT LEE VA 23801-6000

PROJECT MANAGER
PETROLEUM & WATER LOGISTICS
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4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
US ARMY FIELD ARTILLERY SCHOOL
ATTN: ATSF-CD 1
FORT SILL OK 73503-5600

CDR
US ARMY ENGINEER SCHOOL
ATTN: ATZA-TSM-G 1
ATZA-CD 1
FORT BELVOIR VA 22060-5606

CDR
US ARMY ARMOR & ENGINEER BOARD
ATTN: ATZK-AE-AR 1
ATZK-AE-LT 1
FORT KNOX KY 40121

CDR
US ARMY AVIATION CTR & FT RUCKER
ATTN: ATZQ-DI 1
FORT RUCKER AL 36362

PROG MGR, TANK SYSTEMS
ATTN: AMCPM-GCM-SM 1
AMCPM-M60 1
WARREN MI 48397

CDR
US ARMY SAFETY CENTER
ATTN: PESC-SSD (MR BUCHAN) 1
FORT RUCKER AL 36362

DEPARTMENT OF THE NAVY

CDR
NAVAL AIR PROPULSION CENTER
ATTN: PE-33 (MR D'ORAZIO) 1
P O BOX 7176
TRENTON NJ 06828

CDR
NAVAL SEA SYSTEMS CMD
ATTN: CODE 05M4 (MR R LAYNE) 1
WASHINGTON DC 20362-5101

CDR
DAVID TAYLOR NAVAL SHIP R&D CTR
ATTN: CODE 2830 (MR SINGERMAN) 1
CODE 2759 (MR STRUCKO) 1
CODE 2831 1
ANNAPOLIS MD 21402-5067

JOINT OIL ANALYSIS PROGRAM -
TECHNICAL SUPPORT CTR 1
BLDG 780
NAVAL AIR STATION
PENSACOLA FL 32508

CDR
NAVAL SHIP ENGINEERING CENTER
ATTN: CODE 6764 1
PHILADELPHIA PA 19112

PROJ MGR, M60 TANK DEVELOPMENT
ATTN: USMC-LNO 1
US ARMY TANK-AUTOMOTIVE
COMMAND (TACOM)
WARREN MI 48397

DEPARTMENT OF THE NAVY
HQ, US MARINE CORPS
ATTN: LPP (MAJ LANG) 1
LMM/2 (MAJ PATTERSON) 1
WASHINGTON DC 20380

CDR
NAVAL AIR SYSTEMS CMD
ATTN: CODE 53645 (MR MEARNS) 1
WASHINGTON DC 20361

CDR
NAVAL RESEARCH LABORATORY
ATTN: CODE 6170 1
CODE 6180 1
CODE 6110 (DR HARVEY) 1
WASHINGTON DC 20375-5000

COMMANDING GENERAL
US MARINE CORPS DEVELOPMENT
& EDUCATION COMMAND
ATTN: DO74 1
QUANTICO VA 22134

CDR
NAVAL AIR ENGR CENTER
ATTN: CODE 92727 1
LAKEHURST NJ 08733

OFFICE OF THE CHIEF OF NAVAL
RESEARCH
ATTN: OCNR-126
ARLINGTON, VA 22217-5000

CHIEF OF NAVAL OPERATIONS
ATTN: OP 413 1
WASHINGTON DC 20350

CDR
NAVY PETROLEUM OFC
ATTN: CODE 43 (MR LONG) 1
CAMERON STATION
ALEXANDRIA VA 22304-6180

DEPARTMENT OF THE AIR FORCE

HQ, USAF
ATTN: LEYSF (COL LEE) 1
WASHINGTON DC 20330

HQ AIR FORCE SYSTEMS CMD
ATTN: AFSC/DLF 1
ANDREWS AFB MD 20334

CDR
US AIR FORCE WRIGHT AERONAUTICAL
LAB
ATTN: AFWAL/POSF (MR CHURCHILL) 1
WRIGHT-PATTERSON AFB OH 45433-6563

CDR
SAN ANTONIO AIR LOGISTICS
CTR
ATTN: SAALC/SFT (MR MAKRIS) 1
SAALC/MMPRR 1
KELLY AIR FORCE BASE TX 78241

CDR
WARNER ROBINS AIR LOGISTIC
CTR
ATTN: WRALC/MMTV (MR GRAHAM) 1
ROBINS AFB GA 31098

CDR
DET 29
ATTN: SA-ALC/SFM 1
CAMERON STATION
ALEXANDRIA VA 22314

OTHER GOVERNMENT AGENCIES

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION 1
LEWIS RESEARCH CENTER
CLEVELAND OH 44135

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
ATTN: AWS-110 1
800 INDEPENDENCE AVE, SW
WASHINGTON DC 20590

US DEPARTMENT OF ENERGY
CE-151, ATTN:
MR ECKLUND 1
FORRESTAL BLDG.
1000 INDEPENDENCE AVE, SW
WASHINGTON DC 20585

ENVIRONMENTAL PROTECTION
AGENCY
AIR POLLUTION CONTROL 1
2565 PLYMOUTH ROAD
ANN ARBOR MI 48105

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